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dynamics of the ionosphere

RITA C. SAGALYN, Space Physics Laboratory (AFCRL)

A precise matching of theoretical and experimental data on positive ion concentrations in the atmosphere above 150 km has been obtained by AFCRL scientists.

Experimental data, obtained from a positive ion detector aboard a Thor rocket, agreed with theory data which in turn was partly based on laboratory studies to within an error of only two percent. Agreement was obtained at all altitudes between 150 and 500 km.

The study, encompassing work carried out on several research fronts at AFCRL, provides the clearest picture yet obtained of the ionosphere and the dynamics of its formation and dissipation. Key to the AFCRL study is a mathematical formulation describing these mechanisms.

The ionosphere is in the continuous process of creation through the interaction of solar energy with air, atoms and molecules. Of the total solar energy, the most effective of the ionizing radiation for the ionospheric region is found in a narrow range in the ultraviolet spectrum between 100 and 1000 Angstroms. Positive ion-electron production, however, is counterbalanced by their continuous recombination.

The ionosphere is probably the most thoroughly investigated of all physical phenomena. Only within recent months, however, have scientists made any real progress toward the precise understanding of its complex dynamics. Many aspects are still a mystery. Much of the data on the ionosphere derives from propagation research

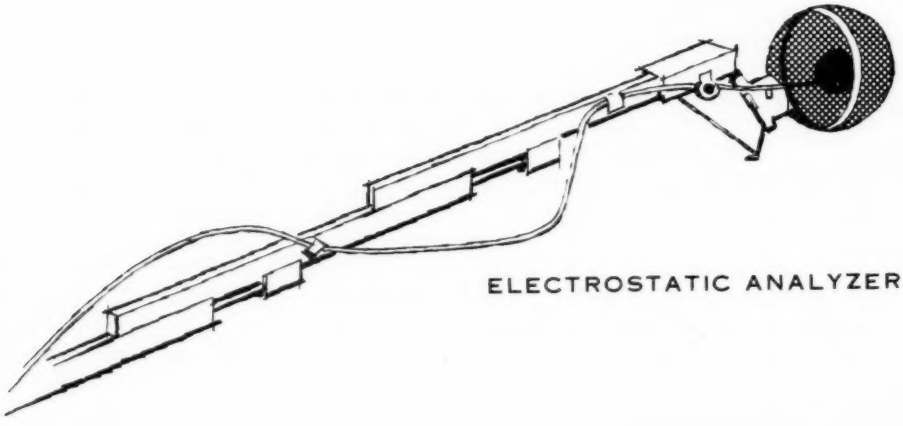
where the primary interest is in the effects of the ionosphere on electromagnetic radiation at various frequencies.

Measurements resulting in the precise matching of the experimental and theoretical data were taken by a Thor rocket fired at 1300 hours at a latitude of 28 N. Analysis of the experimental data and much of the theoretical calculations were largely under the direction of Rita C. Sagalyn and Michael Smiddy of AFCRL. The results are contained in their recently published report, "Measurement and Interpretation of Ion Density Distributions in the Daytime F Region." The altitude of maximum density was measured to be 315 km; the theoretical calculations give 320 km.

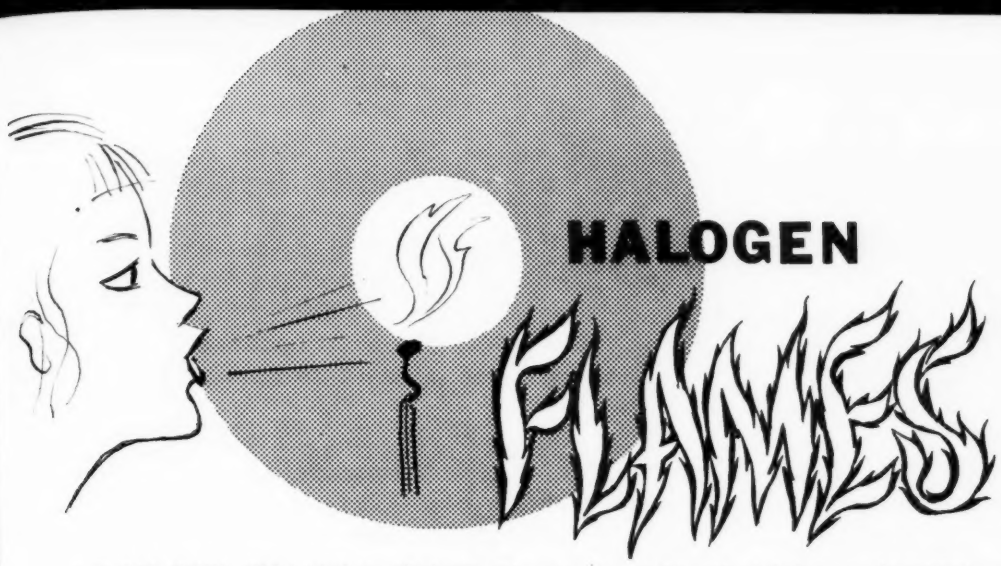
The high accuracy of the rocket experiment data was made possible by an AFCRL-designed electrostatic analyzer. This analyzer consists of two spherical electrodes, one inside the other. The outer electrode is a wire mesh, sphere with a high open-to-surface ratio. Inside the sphere is a second spherical electrode. This analyzer is extended, after booster burnout, on a boom several feet from the vehicle surface to minimize the effects of the space charge sheath around the vehicle. A voltage large enough to collect all positively charged particles which enter the outer grid is applied between these two electrodes. AFCRL scientists also derived the theory for interpretation of the analyzer results when mounted on a moving vehicle in the ionospheric plasma.

In addition to AFCRL's rocket probe experiments, strong reliance was placed on measurements made by others. Exceptionally good data on ion composition, for example, were published by Russian scientists based on measurements made by Sputnik III.

A host of factors are involved in the calculation of ion density in the atmosphere. One of these is the continuously changing nature of the ionosphere itself. Ion density varies with latitude, with season, with the time of day, and with the magnitude of solar disturbances. (AFCRL's theoretical formulations on ion creation and dissipation do not consider the contributions of solar protons which influence ion formation or of cosmic rays).



ELECTROSTATIC ANALYZER



LT COLONEL WILLIAM H. WYATT, Directorate of Chemical Sciences (AFOSR)

As children, it was a most exciting time when we could blow out the flame on the match after grandfather lit his pipe, likewise the curiosities of the scientists were also aroused by the magic of these fiery tongues. From their ingenuity and engineering feats, we now depend upon the energy from flames to cook our food, heat our homes, smelt our ores, drive our automobiles and propel our jet aircraft and rockets. Tomorrow, our space craft may depend upon a flame's energy to probe the universe; therefore a thorough understanding of all aspects of the chemistry of flames will provide better propulsion systems for these flights.

Although hydrocarbon flames have been studied for many decades, flames using halogen containing hydrocarbons have more recently attracted attention in organic chemistry. Dr. J. P. Park (organic chemist) and Dr. J. R. Lacher (physical chemist) of Colorado University have combined their scientific knowledge on "Flames Produced by Burning Fluorine - Containing Olefins". They discovered that chlorotrifluoroethylene, chlorine, and oxygen react to give a luminous flame. The reaction could thus be studied by means of the spectral nature of the emitted light. The spectra were obtained by means of a medium quartz spectrograph and the reaction products were analyzed by means of chromatographic analysis and their infrared spectra.

One interesting feature was the reaction of oxygen alone with chlorotrifluoroethylene. This reaction would produce a blue flame

unless chlorine was utilized to initiate the reaction. After obtaining the luminous flame with oxygen, chlorine and chlorotrifluoroethylene, the oxygen flow is terminated for a few seconds and then the chlorine a couple of seconds later. When the chlorine is terminated the oxygen is again directed into the reaction cell whereby the luminous flame continues with only oxygen and chlorotrifluoroethylene. The flow rate of oxygen is very important because if it exceeds a critical rate the luminous flame lapses into the blue flame.

The most striking feature of the reaction among chlorotrifluoroethylene, oxygen and chlorine is that the reaction is spontaneous at room temperature and in the dark. The initiation process as suggested by Schumacher and co-workers was that the chlorine first reacts with chlorotrifluoroethylene and then the oxygen reacted with this chlorinated product. This was determined by adding oxygen to the hydrocarbon prior to adding chlorine and which gave a negligible rate of reaction. Drs. Park and Lacher counter-proposed that the basic reactions of Schumacher didn't account for the reaction proceeding in the dark and that an energy step involving chlorine molecules is necessary for the reaction to proceed without light.

The simplest type of reaction which would explain the observations is:

$M^* + CL_2 \rightarrow M + 2CL$ where M^* is any molecule or atom with excess energy.

$M^* + M \longrightarrow 2M$

In this mechanism, there are molecules having sufficient energy (excess energy) to promote the reaction. If the mechanism is valid, chlorotrifluoroetheylene, chlorine and oxygen will react rapidly and without light.

By these studies of halogen-containing hydrocarbon flames, the scientist can determine the kinetics of these chemical reactions, the decomposition and combination of especially useful chemical compounds, and chemicals which may release maximum energy. In our aerospace programs, the study of combustion and aerodynamics (aerothermochemistry) will advance our knowledge of propulsion and space materials.

Reference: AFOSR TR-60-126

IMPROVED ACCURACY IN THE LOCATION OF EPICENTERS FOR explosions AND earthquakes

MAJOR WILLIAM J. BEST, USAF, Geophysics Division (AFOSR)

If the depth of focus (source below the surface of the earth) of a seismic event can accurately be determined (to ± 1 Kilometer) then a criterion for distinguishing underground nuclear explosions from earthquakes would be established, because a high percentage of the earthquakes occur in the depth range from 5 to 15 Km. The detonation of nuclear explosions at or near these depths would be economically unfeasible. Using present techniques, the depth of a nuclear explosion, detonated in the salt beds at Carlsbad, New Mexico on 10 December 1961 (Code name GNOME) was calculated to be 40 Kilometers above the earth's surface. The actual depth of detonation was approximately 1200 ft.

Before improvements can be made on the depth of focus determination the accuracy of epicenters (surface location) has to be improved. Under an AFOSR research grant (AF-AFOSR-61-137) Dr. Eugene Herrin, Dallas Seismological Observatory, Southern Methodist University is developing computer techniques to improve the accuracy of epicenter locations with the hope of extending these techniques to the depth of focus problem. Evidence from recent earthquakes and nuclear explosions has shown substantial regional variations in the seismic velocity of the normal P wave (compressional mode) within the Upper Mantle for the United States. These regional variations have a significant effect on the location of the epicenters. Before these regional variations were accounted for, the epicenter error in locating the Gnome explosion was some 30 Kms. Dr. Herrin's new method for computer location of epicenters incorporates these regional variations and has decreased the error of location for seismic event in the Western United States by as much as an order of magnitude. Future work will include a determination of regional variations across other parts of the world, and depth of focus techniques.

PONDEROMOTIVE ACTION

W. G. BRAUN, Plasma Physics Research Laboratory (ARL)

In the course of an investigation of the stabilization mechanism of an electrical arc discharge in a gas flow an experiment involving a small (30 Gauss) magnetic cross field had a surprising result: The arc channel was practically not deflected, although the ponderomotive force exerted with the magnetic field was by many orders of magnitude larger than the weight of the arc column. This apparent rigidity of the arc poses the question: "How is the ponderomotive force balanced without a deflection?" Here is the explanation:

The ponderomotive force is the macroscopic summation of the Loretz forces acting upon each charged particle in the arc plasma. The particles are impeded in their movements by friction with the neutral atoms or they may become neutrals by recombination in the cooler edge of the arc. As the case may be, the impulse imparted to the charged particles appears finally as an impulse of the gas which surrounds the arc. A cross flow in the ponderomotive direction is the result; the flow is maintained by an electromagnetic pump located in the current core of the arc.

In the discharge chamber with the stabilizing flow, the arc channel establishes itself along the locus of symmetry of the cooling conditions. The central region of the flow pattern in the discharge chamber, where the effect of the magnetic field was tested, can be visualized with the aid of Figure 1. This drawing shows only the meridional components of the flow; the rotational component has been left out for ease of representation. Actually, the flow lines spiral around the chamber axis. The region of the flow is rather turbulent. As soon as the magnetic field is applied, the cross flow sets in imparting impulse to continuously renewed fluid elements. The cross flow is being added to the strong stabilizing flow and the impulse produced by the j x B forces is imparted to it. This addition does not change appreciably the original flow and the cooling conditions and the arc channel stays in its original position.

There is, of course, a slight change of the temperature profile of the arc caused by the convective "percolating" cooling by the cross flow. The very small displacements of the arc (about one-twentieth of the diameter) were monitored by observing the edges of

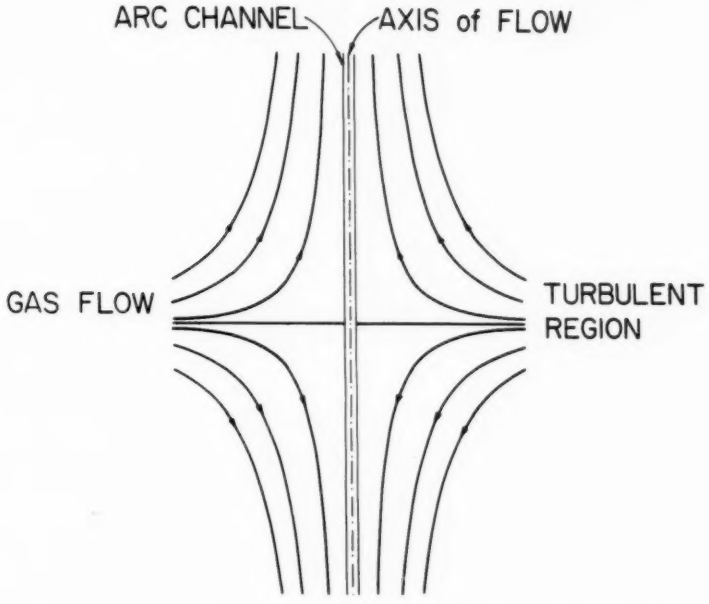


Fig 1 Cooling Flow Around the Arc (Schematic)

the radiation profile with photo cells through narrow slits from two directions forming a right angle. Due to the additional convective cooling the temperature profile sags on the intake side of the cross flow and bulges on the exhaust side.

The flow in the discharge chamber involves also a rotation which is imparted to the gas by pitched inlet nozzles. Cross flow and rotation (Circulation) produce a lift force perpendicular to the ponderomotive direction (Magnus effect) taking the center of rotation and the arc with it. A displacement in this direction has been observed, but it is also very small. This can be explained only with a low rate of rotation. This fact has been corroborated by other measurements.

There are other phenomena which involve the ponderomotive cross flow. If an arc column were established in a large body of

gas which practically is at rest, the electromagnetic pump would create a flow pattern which when mapped on a plane perpendicular to the arc axis resembles the dipole flow (Figure 2). The pump

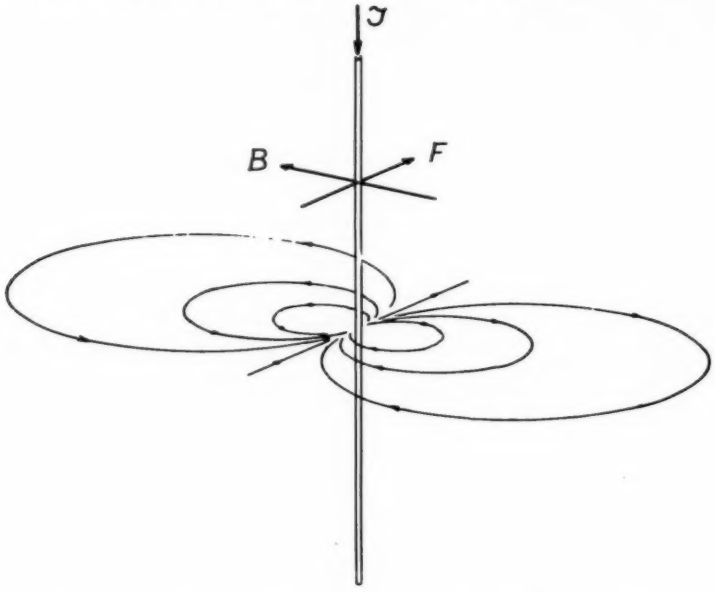


Fig 2 Dipole Type Flow Generated by jxB

can be replaced in thought by a source and a sink located in the arc column. In this flow the force balance will be reached at a higher rate of speed than in the non- recirculating case. Here, the accelerated fluid returns to the pump with an entrance impulse and only the impulse difference imparted in crossing the arc contributes to the force balance. In the steady state the impulse imparted by the pump is dissipated by viscous forces in the flow. The dipole type flow by its cooling effect causes a windward shift of the temperature profile. As the conductivity of a plasma depends largely on the temperature (via the degree of ionization) the conductivity profile and the current profile follow the shift of the temperature. The described chain of events results in a motion of the arc in the ponderomotive direction. The propagation velocity will depend on the rate at which the temperature profile can be displaced.

The pressure difference across the arc inherent to the cross flow should also have an influence on the current profile, because the mobility of the charge carriers in a plasma increases with the re-

duction of the pressure. At lower values of the total pressure, the pressure gradient across the arc may have a larger effect on the conductivity profile than has the distortion of the temperature profile. In this case the conductivity profile shifts backward, taking with it the current core of the arc. The arc should move against the ponderomotive direction (Retrograde motion).

A report describing the details of the experiments and containing a more complete theory is in preparation.

furnaces for semiconductor device fabrication

ROBERT M. BARRETT, Electronic Material Sciences Laboratory (AFCRL)

Four specially designed diffusion furnaces for the fabrication of experimental semiconductor devices have been delivered to AFCRL. The furnaces, designed and built for AFCRL by Hevi-Duty Heating Equipment Company, have the broadest range of accurate operating temperatures known to exist in this type of equipment.

The furnaces control temperatures within one-half degree over a range of 100 to 1,450 degrees C. Such accurate control of temperatures in the lower ranges is unique in diffusion furnaces. Diffusion furnaces are used in depositing impurities onto tiny wafers (usually silicon) which give semiconductors their electronic properties. The process is basic to the fabrication of microcircuits.

The new furnaces, together with existing AFCRL facilities, give AFCRL an exceptionally strong capability for conducting electronics materials research. The AFCRL program includes the purification of semiconductor materials, the growth of a great variety of single crystals, the analysis of crystals, the evaluation

of radiation effects on materials, and the fabrication and testing of experimental semiconductor devices.

The furnaces are built in three sectional modules, with a pre-heat section, a diffusion section, and an after-heat section. A complex control system using solid state devices and highly sophhisticated instrumentation was developed especially for the furnaces. The control devices sense temperature variations in three separate zones of the diffusion section and, through an interlock system, adjust temperatures throughout the entire diffusion section. Similar systems control temperatures in the pre-heat and after-heat sections, although these are operated independently.

Normally, pre-heat section temperatures are in the 600 to 900 degree range. Accurate control in the 100-degree range is unique in this furnace. After-heat sections also are not normally specified in such furnaces.

Accuracy of temperatures to such a fine tolerance is made possible through the development of thermal loss regulators. This design principle is based on a constant loss of heat from the furnace chamber so that additional heat may be continually applied without overshooting the desired temperature. It was also necessary to design the furnaces so that no temperature dips occur in the transition area between sections. Accurate control of temperatures is the most critical stage of semiconductor processing.

ENZYMES: BIOLOGICAL CATALYSTS

CAPTAIN B. D. STOLLAR
Biological Sciences Division (AFOSR)

Macromolecules are increasingly becoming recognized as fundamental stuff of life, as they form the basic structural and functional units of living cells. Intensive research has sought to determine the structure of these giant chain molecules, among them certain proteins named enzymes. Indeed enzymes have been of great help in studying the structures of other enzymes.

Enzymes are biological catalysts. They are made up of long chains of amino acids. There are twenty amino acids in nature and they form the building blocks of all proteins; a "peptide bond" joins each amino acid to its neighbor in a chain. Each enzyme has a structure which is specific both in the sequence of these amino acids and in the way its chains fold in secondary and tertiary configurations. The very specific structure resulting from the unique sequence and folding is the basis for the very specific catalytic activity of the enzyme. Knowledge of the structure and the active configurations within these proteins could contribute greatly to extending the already extensive usefulness of enzymes in research and manufacture.

Proteins are such large molecules, however, that a straightforward analysis of the sequence of amino acids within them is impossible; the chains must first be broken down into smaller pieces which can then be chemically analyzed. The enzyme trypsin is one which can break large protein molecules down in a specific way. Trypsin cleaves a protein molecule only where the amino acids arginine or lysine occur; the resulting products consist of a mixture of polyaminoacid chains (oligopeptides) which can be separated by chromatography and each one analyzed. Other protein splitting enzymes break the molecule into different oligopeptides which can also be analyzed. Overlapping areas may become obvious with the use of

several different enzymes and it has in fact been possible to reconstruct the entire sequence of long chains in this way.

One of the difficulties of this technique is that, although only a small amount of the enzyme is required, its own soluble protein may become confused with that of the protein actually being studied. A new approach to solving this problem has been made by E. Katchalski (AFOSR grantee) of the Weizmann Institute, Israel, who has contributed greatly to the knowledge and methodology of constructing synthetic polymers of amino acids. His objective was to couple the enzyme trypsin onto a completely water-insoluble synthetic polymer so that enzymatic activity would be retained, but the enzyme would remain insoluble and could be easily removed from the reaction mixture. It was obviously necessary to attach the enzyme by a part of the molecule not required for catalytic activity, and it seemed desirable to have the catalytic portion of the whole complex flexible in space and thus capable of contacting substrate molecules. To achieve this, polypeptide side chains (polytyrosyl-) were first built onto the enzyme molecule to serve as the flexible handle for attachment to the insoluble carrier. Then the insoluble polymer was built from p-aminophenylalaine and leucine. Finally, the enzyme was attached to the carrier through its newly acquired polytyrosyl side chain handles.

The new water-insoluble complex retained enzymetic activity (about 20% of that of the free enzyme). It was possible to use the enzyme for its specific purpose and then completely remove it from the scene. Furthermore, an added benefit was that the insoluble enzyme was much more stable to storage and to the conditions of the reaction than was the free enzyme.

Such stability allowed a further extension of the usefulness of this preparation. It was possible to prepare columns of the enzyme mixed with synthetic resins, to allow the substrate on which the enzyme acts to flow through the column, and to thus have continuous action of the enzyme over long periods of time. Twenty milligrams of complexed enzyme was able to cleave four grams of substrate with no loss of activity, each molecule of enzyme thus handling thousands of substrate molecules. The technique thus provides a means for modifying or isolating large amounts of biologically important compounds if extended to other enzyme systems, as well as a means for extended studies in the structure of macromolecules. Through these studies one might also learn of new short-lived inter-

mediates in many enzymatic reactions whose mechanisms of action and whose active sites are being sought. The system may also provide new models for studying surface reactions. All applications leading to a greater understanding of the structure and function of the macromolecules may eventually allow a much greater control over important biological processes than is possible today; indeed, it may be possible to use the great catalytic powers of enzymes, when more fully understood, for complex synthesis of important substances like proteins.

USE OF RADIO STARS TO DETERMINE ANTENNA EFFICIENCY

DR. JULES AARONS, Space Physics Laboratory (AFCRL)

It's fairly easy to calculate the theoretical efficiency of an antenna's given size and type. Once the antenna is built, however, the radar and communications people--and the antenna designer--would like to know whether or not the antenna is performing as it should. Further, although the antenna might perform perfectly well when it is first erected, it can become misaligned in numerous ways. Subtle warping can occur in the dish, the feed can move slightly in relation to the reflector, and so on. How do we know then if an antenna is performing as efficiently as it should?

For smaller antennas, measurement of efficiency doesn't pose a problem. Measurements can be done on an antenna range. Here a transmitter is directed at the receiving antenna, and we can calculate just how much transmitted energy is gathered by the antenna under test as compared to that gathered by a standard gain horn.

But with large antennas such as radio telescopes with dishes larger than 60 feet diameter or so, far field distance requirements are such that the transmitter must be placed at a great distance from the receiver and the conventional antenna range cannot be used. This led to a method, first proposed in 1951, for measuring antenna patterns by using the sun as a transmitter. Still, absolute efficiency cannot be obtained because of the variable temperatures of the sun and its finite size.

As the result of recent theoretical work carried out by Professor H. C. Ko of the Ohio State University, and applied by

John Castelli and Carl Ferioli of AFCRL, it is now possible to measure the absolute efficiency of an antenna at various frequencies by using radio stars as transmitters.

The basic idea is to use the energy from two radio stars, Cassiopeia A and Cygnus A as standard known signals and to obtain signals levels by drift curves. Spectral indices allow these sources to be used at any frequency.

The theoretical work provides for correction of the true antenna pattern-- that is, whether it has a Gaussian antenna distribution, a Bessel function distribution, or otherwise. A correct ion factor dependent on the distribution is then utilized.

By means of the technique the calibration of large operational antennas can be accomplished fairly simply.

AFCRL *notes*

LaVERNE E. WOODS, Research Information Office

Dr. Hans H. Hinteregger of AFCRL has been notified by NASA that his proposed experiment involving an extreme ultraviolet scanning spectrometer has been selected for inclusion in the POGO S-50 satellite. This is the first polar orbit satellite in NASA's orbiting geophysical observatory program. Present plans call for a 1964 launching. (Space Physics Laboratory)

Recently installed at the Joint Arctic Weather Station at Alert, Ellesmere Island, Canada, is an advanced operational meteorological system for making continuous and automatic surface observations. The AFCRL-developed equipment consists of a temperature and humidity sensor system from which data is automatically relayed to the weather station located some distance away. The novel part of this system is a thermoelectric hygrometer that measures frostpoint, or dewpoint at temperatures as low as minus 100 degrees Fahrenheit with great accuracy. The Ellesmere location is thought to be one of the northernmost inhabited areas on the earth. (Meteorological Development Laboratory)

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